ANALYSIS AND OPTIMIZATION OF CONNECTING ROD WITH DIFFERENT MATERIALS

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Abstract

The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modelled using SOLIDWORKS software and to that model, analysis is carried out by using ANSYS 2022 STUDENT Software. Finite element analysis of connecting rod is done by considering the materials, viz… structural steel, stainless steel (304), phosphorus bronze, forged steel. The best combination of parameters like Von misses Stress and strain, Deformation for two-wheeler piston were done in ANSYS software. Forged steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod.

Keywords: connecting rod, crankshaft, materials, ansys

Introduction

Connecting Rod

The connecting rod material is an essential part of the engine. It connects the crankshaft to the piston. It transmits the rotation of the crankshaft towards the piston of the engine. With the help of the 'CR,' the rotational motion (RM) of the crankshaft shifted into the reciprocating motion of the piston. Connecting rod essentials to convey the tensile force and the compressive force from the piston also rotates at both ends.

A connecting rod is the part of a piston engine which connects the piston to the crankshaft. Together with the crank, the connecting rod converts the reciprocating motion of the piston into the rotation of the crankshaft. The connecting rod is required to transmit the compressive and tensile forces from the piston. In its most common form, in an internal combustion engine, it allows pivoting on the piston end and rotation on the shaft end. The predecessor to the connecting rod is a mechanic linkage used by water mills to convert rotating motion of the water wheel into reciprocating motion.

Internal combustion engines

A connecting rod for an internal combustion engine consists of the 'big end', 'rod' and 'small end' (or 'little end'). The small end attaches to the gudgeon pin (also called 'piston pin' or 'wrist pin'), which can swivel in the piston, the connecting rod, or both. Typically, the big end connects to the crankpin using a plain bearing to reduce friction; however some smaller engines may instead use a rolling-element bearing, in order to avoid the need for a pumped lubrication system. Connecting rods with rolling element bearings are typically a one piece design where the crankshaft must be pressed together through them, rather than a two piece design that can be bolted around the journal of a one piece crankshaft. Typically, there is a pinhole bored through the bearing on the big end of the connecting rod so that lubricating oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons and piston rings. A connecting rod can rotate at both ends, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around the crankshaft.

Figure 1. 1. Typical design of automobile engine connecting rod.

Materials

The materials used for connecting rods widely vary, including carbon steel, iron base sintered metal, micro-alloyed steel, spheroidized graphite cast iron. In mass-produced automotive engines, the connecting rods are most usually made of steel. In high performance applications, "billet" connecting rods can be used, which are machined out of a solid billet of metal, rather than being cast or forged. Other materials include T6-2024 aluminium alloy or T651-7075 aluminium alloy, which are used for lightness and the ability to absorb high impact at the expense of durability. Titanium is a more expensive option which reduces the weight. Cast iron can be used for cheaper, lower performance applications such as motor scooters.

Specification of the problem

The objective of the present work is to design and analyses of connecting rod made of Forged steel. Steel materials are used to design the connecting rod. In this project the material (carbon steel) of connecting rod replaced with Forged steel. Connecting rod was created in SOLIDWORKS. Model is imported in ANSYS 2022 STUDENT for analysis. After analysis a comparison is made between existing steel connecting rod viz., Structural steel, SS304(stainless steel), phosphorus bronze, Forged steel in terms deformation, stress.

Literature Review

T. Sathish et al. developed the analysis of different connecting rod materials.
Arthur used three different materials of aluminium as AA 2014, AA 6061, and AA7075. Analysis of the different geometry shape forms of rod connecting, such as the shell types and concrete types, carried out using modelling packages, such as ANSYS and SolidWorks software. As a result, comparing with three different aluminium alloy, 2014 possess the best stiffness and the less weight.

X.Hou et al. discussed that the Connecting rod handles many different types of forces: the occasionally thrusts power from the inactivity force and the piston nail purposed by the reciprocating inactivity force and the connecting rod of the piston types. When improvement is applied, the weight of the model decreased, and the safety factor decreased by 5.4 %. And also give the low deformation of the model. By the conclusion, the displacement and the safety factor of the model improved by 1.7 % and 5.4 %, and the most considerable stress decreased by 4.9%.

B. Sriharsha et al. Showed the design and consideration for the connecting rod. This paper's main point was to improve the design of 'CR,' decrease the weight of 'CR' and change the material of the 'CR.' With the help of the INVENTOR, the 'CR' model created and analysis worked by ANSYS. In conclusion, removing the material from the large side of the connecting rode where the stress values were low. In the research paper, the aluminium alloy or the Ti alloy use to fabricate the connecting rods.

Aisha et al. studied that the integrity and efficiency of automobiles depend on the construction of connecting rods. There are various parameters and conditions under which connecting rods fail on certain loading conditions. Sort of material can also be responsible for the failure in operating the CR. Inexpensive and well qualitative connecting rods can be achieved by optimizing. Their research used the Finite Element Method (FEM) using workbench to calculate the optimization under certain load conditions.

P.S.R. Loga et al. described that connecting rod is held between piston and crankshaft in an internal combustion engine. The primary purpose of the 'connecting rod' is to interval the linear motion into rotational motion. This research was led to analyse the design of connecting roads and use the finite element method by using ANSYS software. They analysed different types of connecting rods. Based on results and calculations, Design created by Solid works software and imported the result on ANSYS. They also performed stress distribution and concentration experiments using ANSYS software. Fatigue stresses also calculated using static structural programmed in ANSYS. Simulation operations were also performed. They made different designs and compared the result. So, they kept the slope of acute 10 degrees. They got success in modification structure, which provides the improvements in the basic original structure.

Mr. A. Karthikeyan et al. researched on connecting rods functions. Connecting rod located in the middle of crankshaft and piston. The primary task of CR is to give the "TO and FRO" motion to the piston and crankpin so that it can convert the reciprocating motion to the rotatory motion of the crank. Their project narrates the designing and analysis of connecting rod and piston. They studied the previous manufactured designed connecting rod made by steel alloy. They used "Solid works" having model 2013 and analysis made by using "ANSYS" software. Finite element analysis experiments were done by using different materials—various parameters like Von-Misses stresses and deformations calculated on "ANSYS" Software. A comparison of experimental and original results was made.

Kapil Tekade et al. studied the creation of connecting rods using different types of materials. Connecting rod is the principal chain or a path between piston and crankshaft in an internal combustion engine. The primary objective of 'CR' is to provide power and deliver the power from piston to crankshaft. All of the necessary experiments of the connecting road were all about within the range of two materials used, i.e., "Aluminium" and "Steel." 'CR' made up of these two materials are used in various engines.

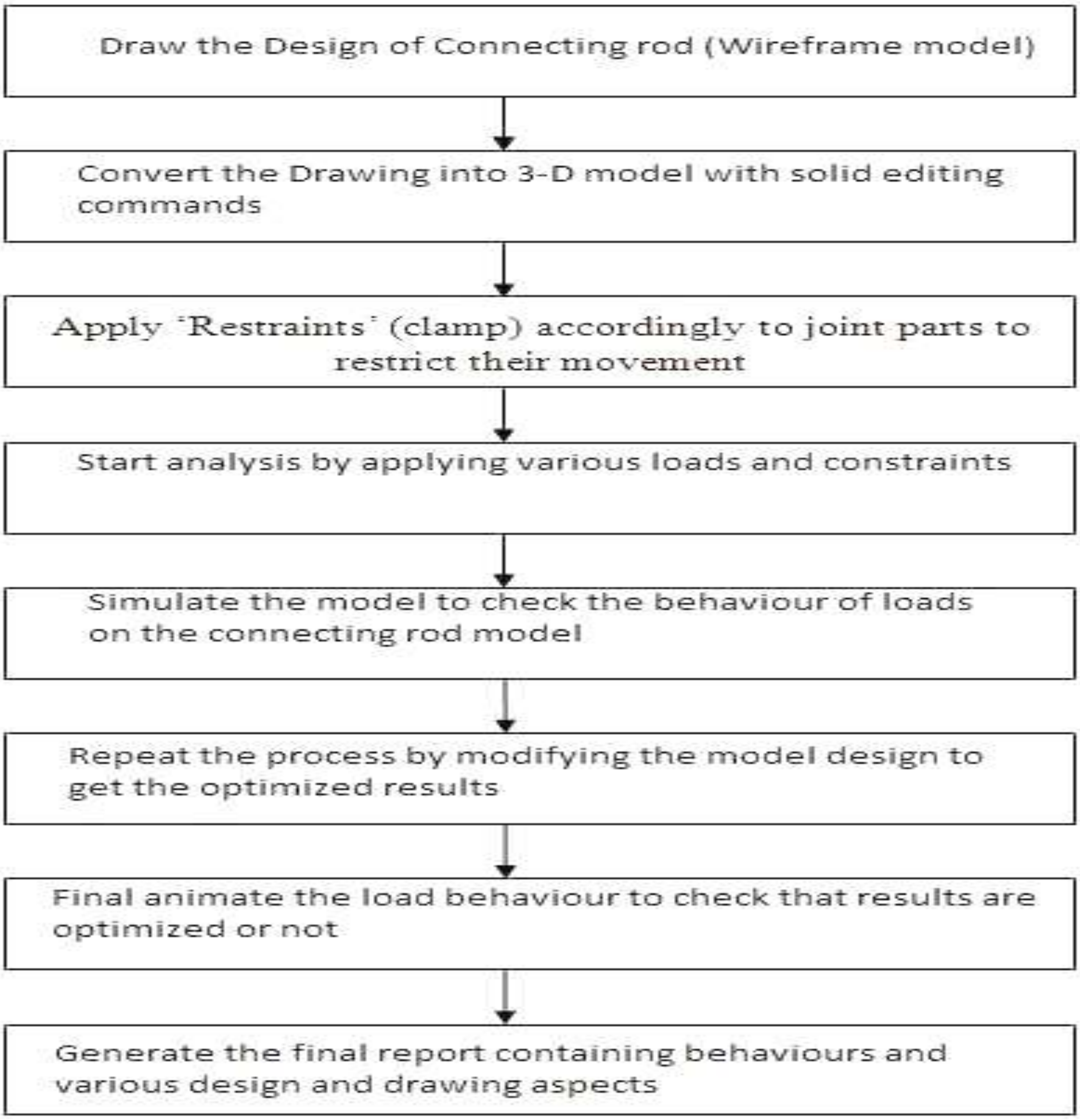
Figure 2.1: Different connecting rods

In this paper, the connecting rod was fabricated by four different aluminium alloys. After comparing the four materials of aluminium alloy, the AA7068T6511 gives a better result.

This section includes the literature survey of earlier research work made by various researchers on connecting rod. Various researchers presented the different techniques in the development of connecting rod and their optimization. This section presents the summary of these research works. 1. Pai (1996) presented an approach to optimize shape of connecting rod subjected to a load cycle, consisting of the inertia load deducted from gas load as one extreme and peak inertia load exerted by the piston assembly mass as the other extreme, with fatigue life constraint. Fatigue life defined as the sum of the crack initiation and crack growth lives, was obtained using fracture mechanics principles. The approach used finite element routine to first calculate the displacements and stresses in the rod; these were then used in a separate routine to calculate the total life. The stresses and the life were used in an optimization routine to evaluate the objective function and constraints.

Kuldeep B "Analysis and optimization of connecting rod using ALFASiC composites". Generally connecting rods are manufactured using carbon steel and in recent days Aluminium alloys are finding its application in connecting rod. In this work connecting rod is replaced by Aluminium based composite material reinforced with silicon carbide and fly ash. And it also describes the modelling and analysis of connecting rod. FEA analysis was carried out by considering two materials. The parameter like von misses stress, von misses strain and displacements were obtained from ANSYS software. 3. Prof. N.p.doshi "analysis of connecting rod using analytical and finite element method". The most common types of materials used for connecting rods are steel and aluminium. Connecting rods are widely used in variety of engines such as, in-line engines, V-engines, opposed cylinder engines, radial engines and oppose-piston engines. For the project work we have selected connecting rod used in light commercial vehicle of tata motors had recently been launched in the market. We found out the stresses developed in connecting rod under static loading with different loading conditions of compression and tension at crank end and pin end of connecting rod.

METHODOLOGY



This paper includes the selection of optimal design of connecting rod which is considered to give better results as compared with the previous results maintaining various parameters which make sure that the optimal design and better results are result of findings and analysis of connecting rod by making various modified designs. Then the Finite Element Analysis method is applied on this design to get the optimized results with the help of various Computer Aided Engineering tools and software.

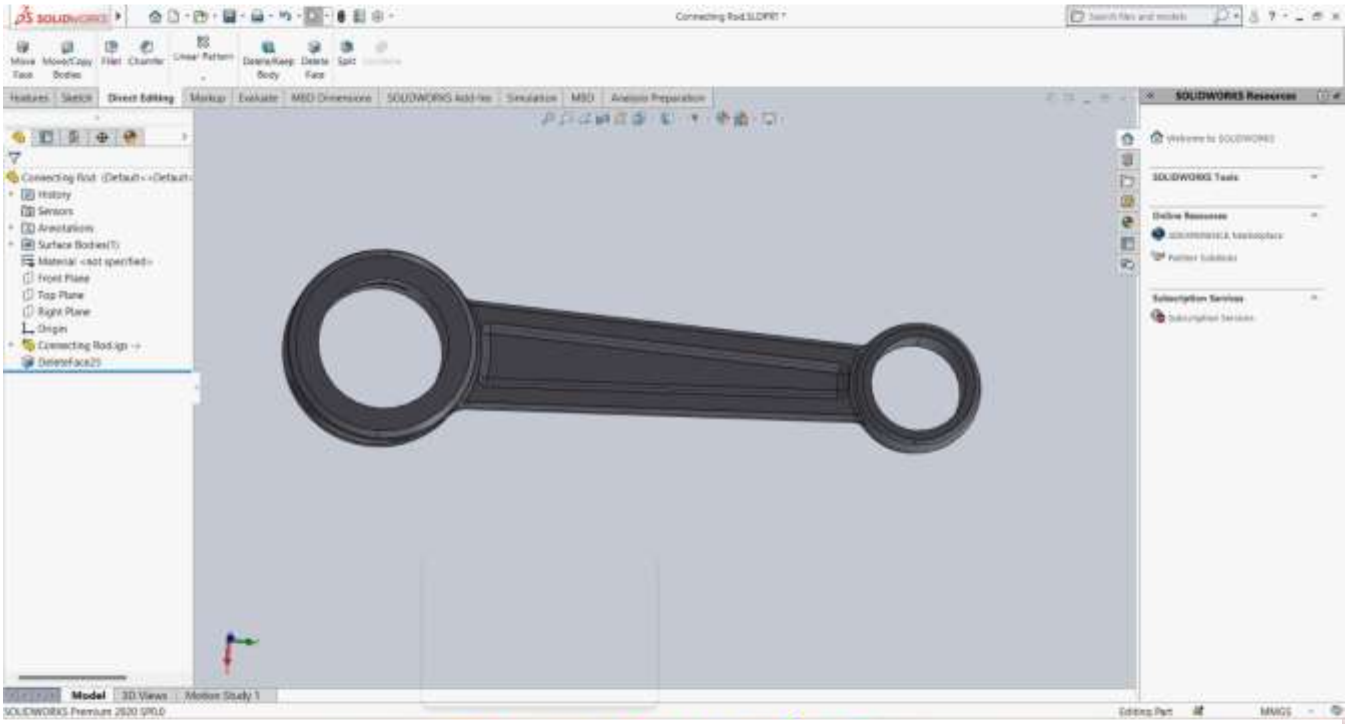


Figure 3.5 Final view of connecting rod

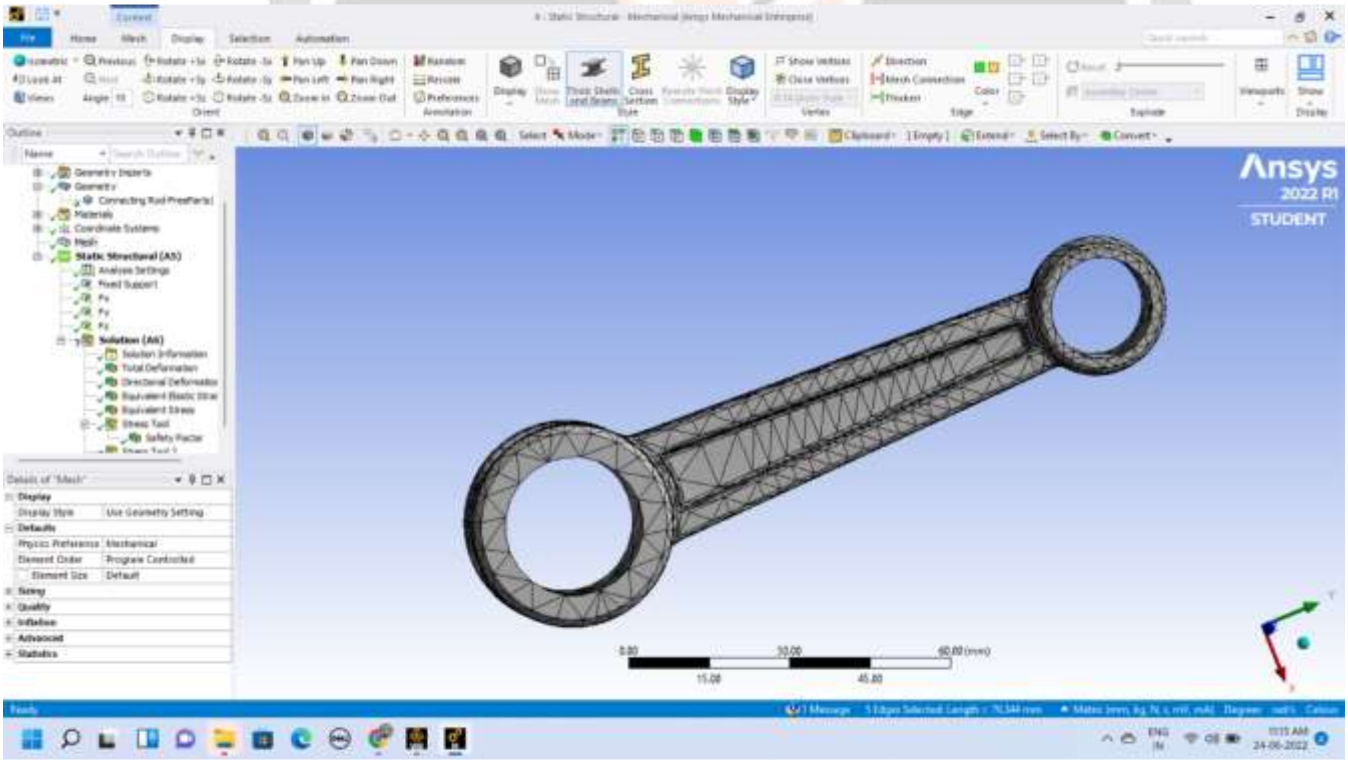


Figure 3.7 Meshing view

DESIGN AND PRESSURE CALCULATION

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the Rankine formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod,{or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

Pressure Calculation for 150cc Engine Suzuki 150 cc Specifications

Engine type air cooled 4-stroke

Bore x Stroke (mm) = 57×58.6

Displacement = 149.5 CC

Maximum Power = 13.8 bhp @ 8500 rpm

Maximum Torque = 13.4 Nm @ 6000 rpm

Compression Ratio = 9.35/1

Density of Petrol C_8H_{18} = 737.22 kg/m3

= 737.22E-9 kg/mm3

Temperature = 60 o F

= 288.855 o K

Mass = Density × Volume

= 737.22E-9 x149.5E3

= 0.11kg

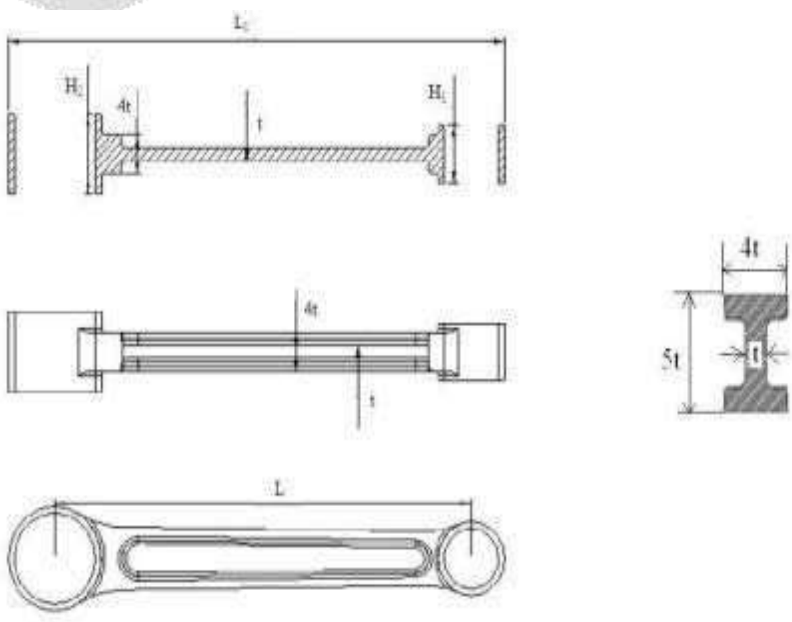
Molecular Weight of Petrol 114.228 g/mole From Gas Equation,

PV = Mrt

R= Rx / Mw

= 8.3143/114228

= 72.76



$$P = \frac{0.11 \times 72.786 \times 288.85}{149.5E3}$$

P = 15.5 Mpa.

Figure 4.1 2D view of connecting rod

4.1 DESIGN OF CONNECTING ROD

In an internal combustion engine, most stressed part is connecting rod. There are different types of stresses induced in connecting rod. One of them is force of gas pressure which is induced by combustion of fuel in the cylinder so that a high compressive force is acted on the piston pin. And the other one is inertial force which is caused by reciprocating of piston. Connecting rod can be made of different type of materials. In modern era it is generally made of steel, but it can be made of aluminium (reducing the weight and the ability of absorbing high impact) or titanium alloy (for high performance engines) or cast iron for two wheeler like scooters, mopeds, etc. In this project study three materials Aluminium-360, Forged Steel, & Titanium Alloy are considered for Ansys.

Engine Specification:-

1. Engine Type – S.I, 4 Stroke, Air Cooled Engine
2. Displacement – 149.5 cc
3. Bore × Stroke – 57 mm × 58.6 mm
4. Maximum Power – 13.8 bhp @8500 rpm
5. Maximum Torque – 13.4 Nm @6000 rpm
6. Fuel Used – Petrol (C8H18)

- **Calculation for Gas Pressure**

Mass of Fuel (M_f) = density of fuel × Volume of cylinder

M_f = 0.11 Kg

Temperature = T (60^{o}C = 288.85^{o}K)

Specific Gas Constant ($R_{Specific}$) = R_{Air} / M_P

$\therefore R_{Specific}$ = 72.786 J K^{-1} Mol^{-1}

Therefore by using Ideal Gas Law,

PV = MRT

$\therefore$ P = 15.5 Mpa

- **Calculating Load Acting on Connecting Rod by Gases**

  $F_1 = (\Pi/4) \times (\text{bore})^2 \times$ Gas Pressure (P)

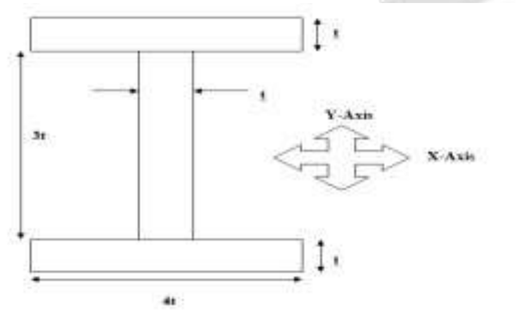
  $\therefore F_1 = 39.552 \times 10^{3}$ N

- **Calculation for Buckling Load**

  W_B = Load acting of connecting rod (F_1) × F.O.S

  $\therefore W_B = 37663$ N

- **Calculation for Moment of Inertia around both the axis of I-Section**



$I_{xx} = 34.91\ t^4$

$I_{YY} = 10.91\ t^4$ Area of Section (A) = 11 t^2 Height of Section (H) = 5t

Width of Section (B) = 4t

Therefore, by using Rankine's Formula

$$W_B = \sigma_c \times A / 1 + \alpha\ (L / K_{xx})^2$$

by solving the Rankine's Formula, we get the value of '**t**' as 3.2 mm.

- **Design of Small End**

  $F_g = d_1(\text{inner dia.}) \times l_1 \times P_{bp}$

  $\therefore d_1 = 17.94$ mm $l_1 = 1.5 \times d_1 = 26.94$ mm

  Outer Diameter (d_2) = $d_1 + 2\ t_b + 2\ t_m$

  $\therefore d_2 = 31.94$ mm

- **Design of Big End**

  $F_g = d_3(\text{inner dia.}) \times l_2 \times P_{bp}$

  $\therefore d_3 = 23.88$ mm

  $\therefore l_1 = 1.0 \times d_3 = 23.88$ mm

Outer Diameter (d_4) = $d_3 + 2\ t_b + 2\ t_m + 2\ b_d$

$\therefore\ d_4 = 47.72$ mm

From above calculations following values of Connecting Rod were obtained

S-no	Parameters (mm)
1	Thickness of the connecting rod (t) = 3.2
2	Width of the section (B = 4t) = 12.8
3	Height of the section(H = 5t) = 16
4	Height at the big end = (1.1 to 1.125)H = 17.6
5	Height at the small end = 0.9H to 0.75H= 14.4
6	Inner diameter of the small end = 17.94
7	Outer diameter of the small end = 31.94
8	Inner diameter of the big end = 23.88
9	Outer diameter of the big end = 47.72

e 4.1 parameters of connecting rod

4.2DETERMINATION OF FORCES

S.no.	Parameters	Value
1	ed of IC Engine	1800 r.p.m
2	e Diameter	100mm
3	ss of reciprocating parts	2.25 kg
4	tor of safety	6
5	ung's modulus	2.1 X 10^5 MPa
6	sson's ratio	0.3
7	nsity of material	8000kg/m^3
8	ll pressure for piston rings(oil rings)	0.137 MPa
9	nber of rings	3
10	efficient of friction	0.05
11	losion pressure	3.15 MPa
12	ton pin diameter	29 mm
13	nk pin diameter	44 mm

Table 4.1.1: Design specification of connecting rod

Forces acting on connecting rod

Following are the forces acting on connecting rod (i) Force on the piston due to gas pressure.

(ii) Force due to inertia of the connecting rod and reciprocating mass.

(iii) Force due to friction of the piston rings and of the piston.

Forces calculation

i). Force due to gas pressure

Maximum force due to gas pressure,

$$Fa = (\pi \times d^2 \times Pe) / 4$$

$$= (3.14 \times 100^2 \times 3.15) / 4 = 24{,}740N$$

ii). Inertia force due to reciprocating mass

$$Fi = M \times \omega^2 \times r \times (\cos\Theta + (r \times \cos\Theta) / l)$$

$$= 2.25 \times (2 \times 3.14 \times 1800)^2 \times 22 \times (\cos 0 + (22 \times \cos 0) / 380) = 1756N$$

iii). Frictional force

The force of friction due to piston rings and piston is,

$$Ff = h \times \pi \times d \times i \times pr \times \mu$$

$$=635.23 \times 3.14 \times 100 \times 3 \times 0.137 \times 0.05$$

$$= 4099N$$

iv). Force acting on piston

$$F = Fgas + Finertia - Ffriction$$

$$= 24{,}740+1756-4099$$

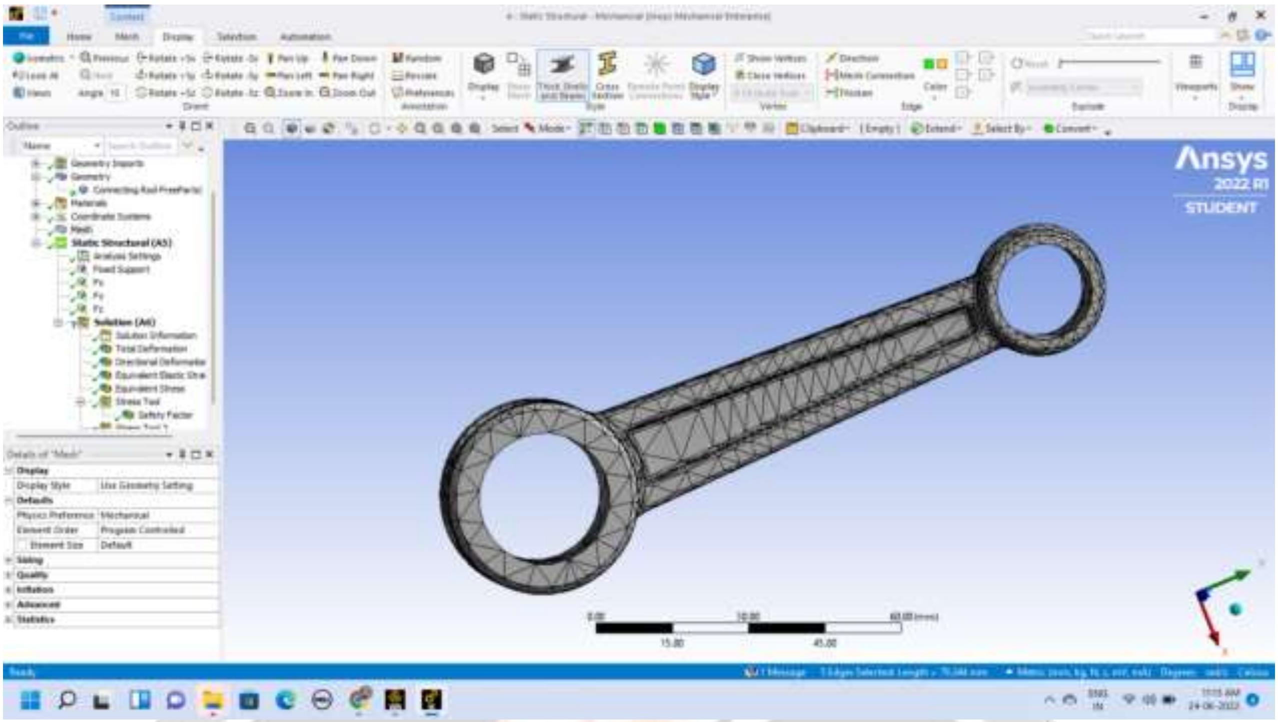
$$=22{,}397N$$

V). Force acting on connecting rod

$$Fc = F / \cos\beta \text{ [At top dead center } \beta=0] \quad =22{,}397 / \cos 0$$

$$= 22{,}397N$$

ANALYSIS OF CONNECTING ROD



7.1 Structural steel :-

ANALYSIS ON GRAPH AND RESULTS

Strictly speaking, graph analysis refers to utilizing advanced algorithms that automatically identify the relationships between entities.

With the above definition, graph analysis can include things like identifying the shortest path between two entities, or automatically recognizing the most significant entities in a network. Such analyses are done on a network graph, which can be thought of as a diagram where each node represents an entity (where an entity can be a person, location, phone, etc.) and the connections between those entities are known as links.

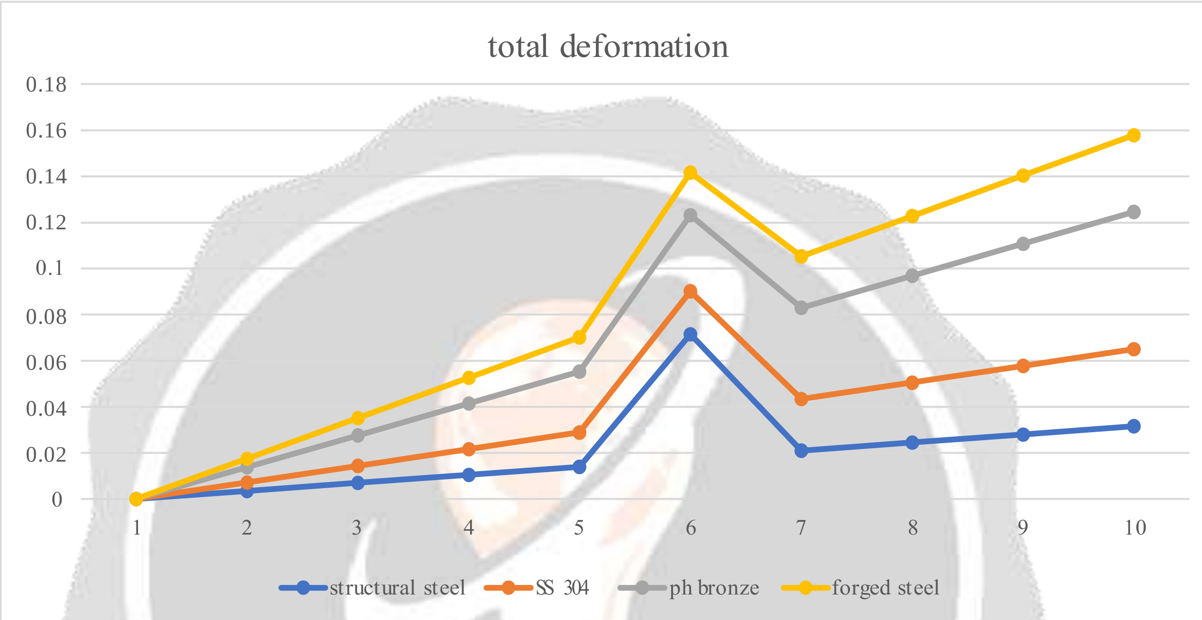
In practice, graph analysis often refers to the more basic identification, visualization and analysis of the relationships between entities. This makes the term somewhat interchangeable with the terms link analysis and network analysis.

Table of parameters for total deformation

RUCTURAL STEEL	304	BRONZE	RGED STEEL
)35089	)37193	)66145	)36999
)70179	)74387	13229	)73998
10527	11158	19843	111
14036	14877	26458	148
71545	18597	33072	185

21054	22316	39687	22199
24563	26035	46301	25899
28072	29755	52916	29599
31581	3347	5953	33299

Table 8.1 total deformation parameters



Graph for total deformation

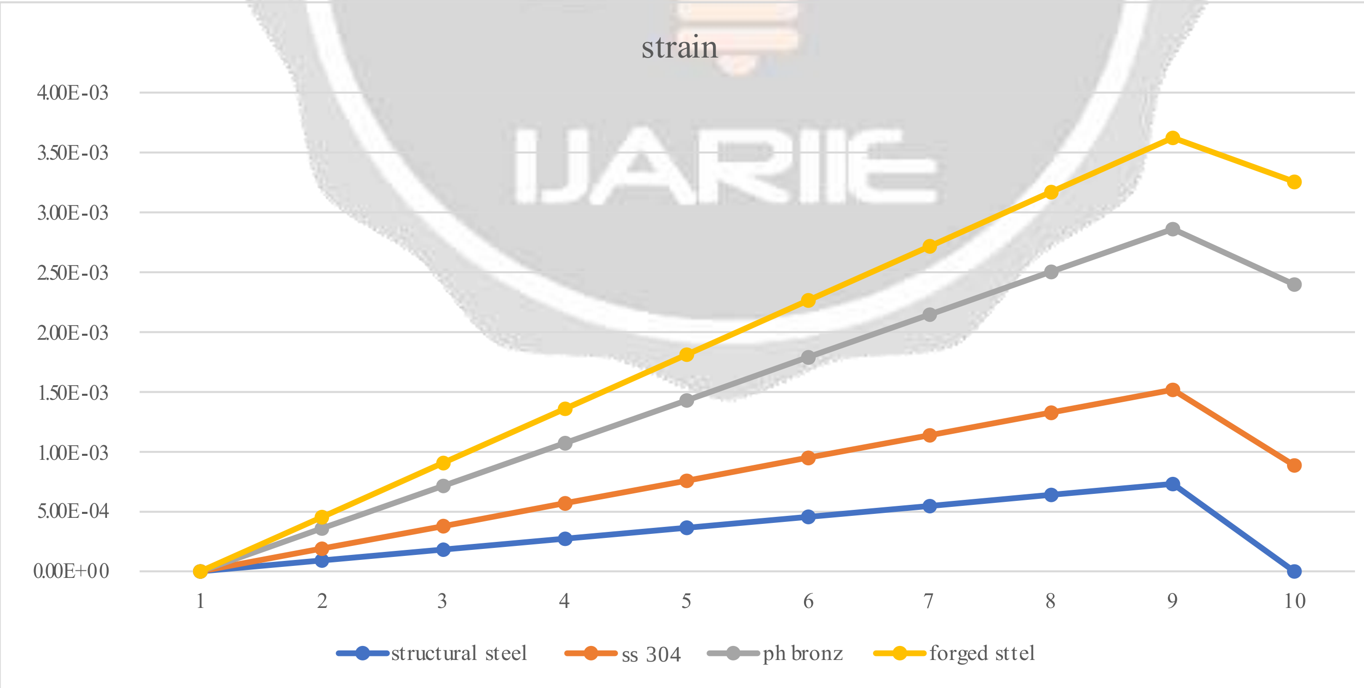
Graph 8.1 total deformation graph

Table parameters for strain

structural steel	ss 304	ph bronz	forged steel
8.90E-08	3.70E-08	1.88E-07	6.72E-08
9.14E-05	9.84E-05	0.00016818	9.54E-05
0.00018265	0.00019677	0.00033617	0.00019078
0.00027394	0.00029514	0.00050417	0.00028614
0.00036522	0.00039351	0.00067216	0.0003815
0.0004565	0.00049188	0.00084015	0.00047686
0.00054778	0.00059025	0.0010081	0.00057221
0.00063907	0.00068862	0.0011761	0.00066757
0.00073035	0.00078699	0.0013441	0.00076293
	0.00088536	0.0015121	0.00085829

Table 8.2 parameters for strain

Graph analysis for strain



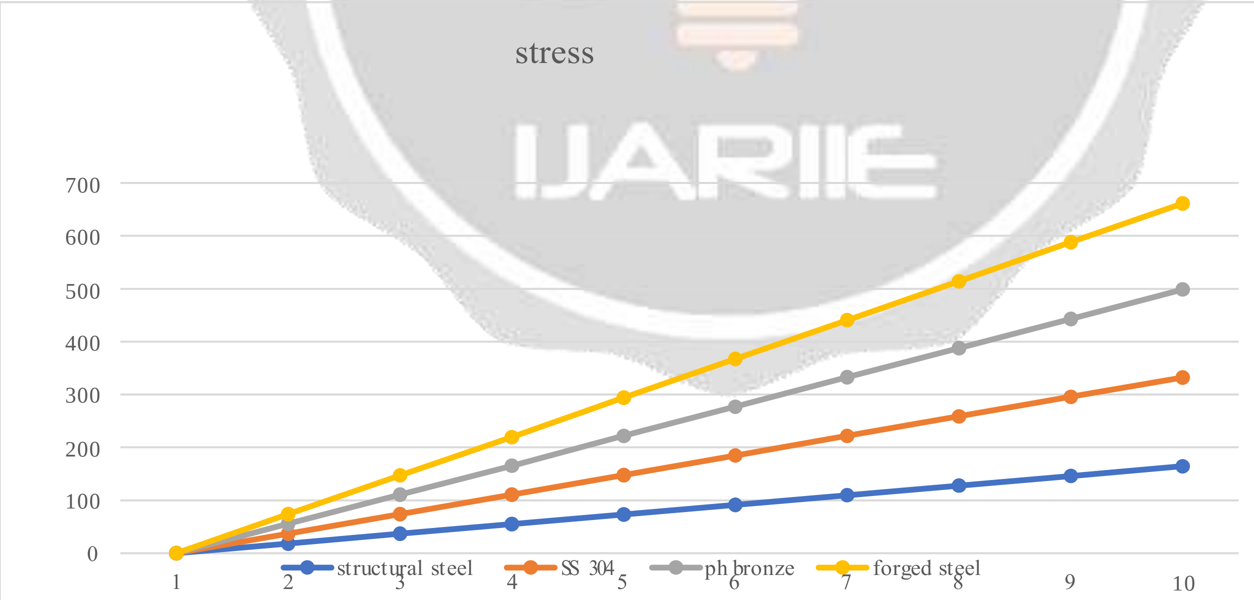
Graph 8.2 graph of strain

Table parameters for stress

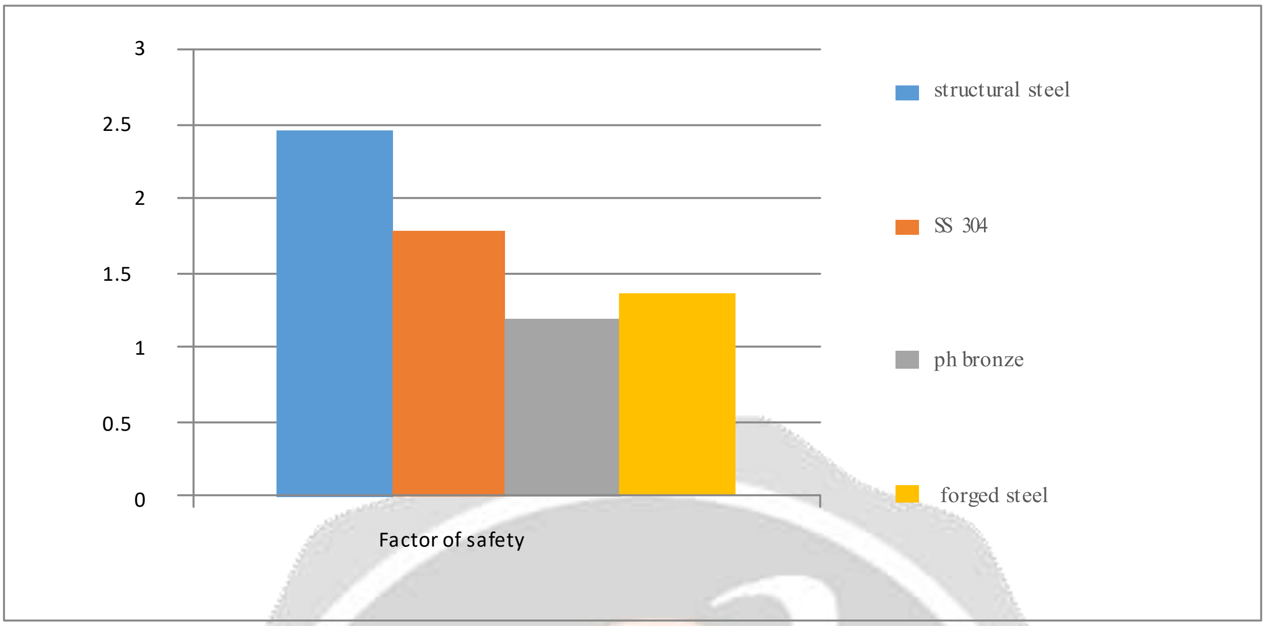
structural steel	SS 304	ph bronz	forged steel
0.004329	0.0044815	0.0043892	0.0069831
18.252	18.69	18.471	18.104
36.499	37.376	36.939	36.202
54.747	56.062	54.406	54.299
72.994	74.748	73.837	72.396
91.241	93.434	92.34	90.494
109.49	112.12	110.81	108.59
127.74	130.81	129.27	126.69
145.98	149.49	147.74	144.79
164.23	168.18	166.21	162.88

table 8.3 parameters of stress

Graph analysis for stress



Graph 8.3 graph on stress



Graph 8.4 Factor of safety

CONCLUSION

Various designs of connecting rod have been analysed in this report and finally an optimal design has been selected for Finite Element Analysis. Using ANSYS 2022 STUDENT SOFTWARE and SOLIDWORKS, Various results are found out and compared with the existing results. It has been found out that the study presented here has come up with better results as well as safe design of connecting rod under permissible limits of various parameters and safe stresses.

- Current work has concluded up with the fact that slight and careful variation in design parameters can give a good design which can be made feasible by a number of analysis using CAE tools and Software.
- Static and Fatigue, both analysis are important as both showed up different aspects of factors on which care should be taken before finalizing any part design.
- It was observed that connecting rod made up of structural steel has higher intensity of stress induced as compared to connecting rod made up of carbon steel.

- Also, there is a great opportunity to improve the design hence structural steel is better choice for connecting rod

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Because of the findings at Ephesus and Gerasa the invention of the crank and connecting rod system has had to be redated from the 13th to the 6th c; now the Hierapolis relief takes it back another three centuries, which confirms that waterpowered stone saw mills were indeed in use when Ausonius wrote his Mosella.

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